THE IRON ORES OF OHIO.

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The geological series of Ohio begins with rocks of Lower Silurian age, and extends well toward the close of carboniferous time. Iron ore is mined in but one of the ten or more leading formations into which the scale is divided.

In the Lower Silurian rocks of the State no notable accumulation of iron, except the sulphide, is found.

In the Clinton limestone of Upper Silurian age, there is a moderate development of the "fossil ore," for which this formation is famous. The Clinton ore has been found in three counties of Southwestern Ohio, viz., Clinton, Highland and Adams. It has been mined in but one, viz., Clinton, and there but on the smallest scale. A small furnace was built on Todd's Fork, a few miles northwest of Wilmington, many years ago, upon the outcrop of the Clinton limestone, which carries at this point a few feet of lean, calcareous ore. The details of the experiment have not been recovered, but it is certain that a little iron was produced by the furnace in its brief history. It made but a single blast.

The ore is quite in keeping with the general character of this anomalous and remarkable deposit. It is a red hematite, sometimes consisting of flattened grains, and sometimes replacing and intermixed with a highly fossiliferous limestone. Red rocks are, as a rule, barren of fossils, the presence of the salts of iron in water to any considerable amount being fatal to most forms of life; but in the Clinton ore we have a rock abounding in the characteristic fossils of Upper Silurian time, and yet carrying enough red oxide of iron to make it one of the valuable ores of the country.

The ore of which we are now treating is lean. The rock is, in fact, a limestone rather than an ore. In Clinton county it is remarkably rich in fossils; a number of species new to science have been derived from the very outcrop which was worked for ore. Among the fossils that it contains, in addition to the coarser and stronger forms, there are lace corals in excellent preservation, and crinoidal remains in great profusion. Part of the ore bed is in reality a crinoidal limestone. These facts are unexplained; but similar facts are found in connection with the ore of this formation through its whole extent, from Lake Ontario to Alabama.

In the southern part of Highland county, near Sinking Springs, and in the adjacent portions of Adams county, a heavier and more promising outcrop of the ore occurs. Reference is made to it in the Report of Progress for 1870, page 268. Natural exposures of the series are found here, which contain beds of ore of fair quality, from one to two feet in thickness, but in the absence of exploration positive conclusions as to the steadiness and value of the deposits are not warranted. Such facts as can be observed suggest a a doubt as to their persistency. A partial analysis of the richer portions of the ore by Professor Wormley gave the following results:

Carbonate of lime	48 00
Metallic iron	30 00
Phosphoric acid	1 28

No great expectations need be entertained as to this ore in Ohio as a source of iron, but there is a possibility that some valuable beds may yet be found.

In the Niagara limestone of Adams county a small amount of iron ore exists. It occurs in depressions upon the upper surface of

the limestone, buried in the clays that result from the decomposition of the bedded rock. When these clays are removed, masses of a soft limonite, resembling bog ore in structure, are found. From a single pocket eight or ten feet deep, and twelve or fifteen feet in diameter, several tons have been taken out. The Brush Creek Furnace was built in the valley of the same name, in the early days of iron manufacture in Ohio, to work these newly found deposits. As might be expected from so precarious a supply, the furnace was soon stopped for want of ore. There is no reason to believe that this source of iron will ever again be brought into use.

No iron ore occurs in the next succeeding member of the Ohio scale, viz., the lower Helderberg limestone, nor is any known in either the Devonian limestone or the Devonian shale, but springs issuing from the latter sometimes form considerable deposits of bog ore. In the great Waverly Group of Sub-carboniferous age, more favorable conditions for iron production occur, and we begin to find ore segregating from the clays and shales in distinct horizons. None of these accumulations, however, are regularly mined in the State, and none, so far as known, have ever been mined, except in occasional trial pits. The seams are at once uncertain, thin, and of doubtful quality. The only localities where any attempts are made to obtain ore from the Waverly Group is in the vicinity of the westernmost furnaces of the Hanging Rock district. Here all horizons that promise supply are tested, and among others these unlikely sources of iron are occasionally tried.

The Sub-carboniferous limestone, which is sparingly developed, and more sparingly worked in Ohio, carries a block ore of approved quality on its upper surface, and occasional kidneys of ore in the clays above it. This ore has been worked to a small extent in Scioto, Jackson and Perry counties in connection with the limestone which supports it. Wherever the latter has been worked for furnace flux, a little of the ore has been brought out with it, but at the present time other limestones have entirely supplanted these thin and impure beds of Sub-carboniferous age. That the ore is not a strong or persistent body is evident from the fact that all production of it ceases with the working of the limestone.

The Carboniferous Conglomerate that comes next in the scale is an iron bearing horizon to a limited extent. There is often a sheet

of ore of a few inches in thickness intermixed with the pebbles of its upper surface. The coarse and worthless ore once mined at Scioto Furnace under the name of the Guinea-fowl ore, belongs to the Conglomerate horizon, but no valuable deposit has been found in this formation, and none is likely to be found.

The iron ores now mined in Ohio belong without exception to the division next reached in ascending the geological series, viz., the Lower Coal Measures. The discussion of this group of ores will occupy the present chapter. Before entering upon it, however, brief mention will be made of the two remaining sections of the Ohio scale, viz., the Barren Measures and the Upper Coal Measures, which will be treated together.

The Barren Measures contain a notable quantity of iron, as the red color of the heavy beds of shale that form so conspicuous a part of them indicates, but the same fact points to the diffusion of the iron in a valueless form. The same general statement can be made for the Upper Coal Measures. There is occasional concentration of ore in connection with limestone and clay deposits throughout the series. When the Cambridge limestone, for example, is worked for furnace flux, a thin plate of good ore is often found to cover it, but the ore is never sought by itself. In some cases there is a blending of ore with the earthy limestones of the Freeport or Bush Creek type, which forms beds of several feet in thickness, and which has good weight, but which generally runs so low in iron and so high in silica as to be without value. They seldom reach 30 per cent. of metallic iron. Many attempts have been made to mine and work these ores, which occur in several distinct and fairly persistent horizons. One of these deposits will be treated briefly on a subsequent page.

In one case, at least, a charcoal furnace was built in Southern Ohio that was to rely upon one of these voluminous Barren Measure ores, but the life of the furnace was brief. After a single blast of short duration, the furnace passed into one of the "picturesque ruins" to which so many of the charcoal iron furnaces of the Appalachian field have heretofore been doomed to come. One ore of a different character that belongs to both the Barren Measures and the Upper Coal measures deserves to be mentioned here. In the red clays that lie near or sometimes replace the limestones of these series, nuggets of red hematite of high grade are often found.

They range in size from pellets up to masses weighing 50 or 75 pounds. Being of high specific gravity and insoluble, they accumulate in the water-courses and on weathered outcrops, and thus suggest a greater abundance of ore than there really is. In only one district of Ohio have they been found gathered into anything like a seam that would justify mining. In one or two townships of Noble county, at a horizon of about 150 feet above the Barnesville coal seam (No. 8c), there is a good promise of deposits that could be worked with profit if transportation were available. The clay that holds the ore is but a few feet in thickness, and the aggregate of the ore makes a respectable part of the entire thickness.

In most cases it would require the sifting of many feet of clay or shale to secure an average of an inch of ore. The quality is of the best. The ore will yield 60 per cent. and upwards of metallic iron, but in practically the whole field that these nodules occupy, the quantity is too small to justify working under the present conditions of iron manufacture. This ore, in other words, has no present value, and it does not seem probable that it can ever be profitable to mine it. Each new observer that comes into the field, however, will be impressed with its intrinsic excellence, and will need to justify himself by independent observations that it does not exist in such a condition as to warrant mining before he will be willing to abandon so promising an addition to the iron making materials of Ohio.

There is not a single seam of ore above the Mahoning sandstone that is regularly mined in Ohio at the present time.

As has already been stated, all of the native iron ores of the State which are turned to present account for furnace use are derived from the Lower Coal Measures. One or two trifling exceptions have been already noted in the cases of the block ore borne by the Sub-carboniferous or Maxville limestone and the rough ore that caps the conglomerate, but the statement scarcely requires qualification for such exceptions as these.

The ores of the Lower Coal Measures were all accumulated under the same general conditions, *i. e.*, as carbonates of iron in the marshes and swamps of the period to which they are referred, but they have assumed several distinct forms which afford a convenient basis of classification.

They can be divided into the following groups:

I. The stratified or mechanically-formed ores.
II. The concretionary or chemically-formed ores.

The first group includes all those ores that bear the marks of having been accumulated in water, or at least in successively formed horizontal sheets, after the fashion of ordinary sediments. The carbonate of iron that they contain has, of course, had a chemical history similar to that of the same mineral in other ores, but the arrangement of the carboniferous or shaly matters with which the iron is associated is due to stratification. These ores are variously known as blackband ores, clayband ores and "flag" ores. They contain, as a rule, a smaller percentage of iron than the other ores of the series, but compensation for their poverty is made in whole or in part by their greater volume, and also by the character of the foreign matter sometimes associated with them. There is often enough carbonaceous matter in the seam to effect the calcination of the ore, and by the expulsion of the carbonic acid of the ore, and by the combustion of the organic matter of the seam, the proportion of metallic iron is raised from 25 to 50 per cent. In volume, as compared with the other ores of the series, they may almost be said to give feet for inches, the maximum that they attain being 19 feet, and the working thickness of large areas rising to 6 feet and over.

The ores of this class are worked at three or more distinct horizons of the Lower Coal Measures of Ohio, and are of great economic importance.

The second group includes those ores that owe their present forms to the obscure agency to which we give the name of concretionary force, a force which is allied to chemical force to this extent, that it gathers up and unites the previously scattered atoms of one or more chemical compounds. Of this group there are three distinct subdivisions, which are named below:

(*a.*) Kidney ores.
(*b.*) Block ores.
(*c.*) Limestone ores.

The ores in which concretionary force is most distinctly shown are those known as *Kidney Ores.* They consist of masses of impure carbonate of iron, often rudely discoidal or ellipsoidal in form, and always bounded by curved surfaces. As a rule, they

are composed of concentric layers or shells which are made very distinct by weathering. They sometimes have hollow cavities within, after weathering, and sometimes enclose masses of clay. Some of them, however, are crystalline at their centers, containing calcite or barite, or occasionally sulphide of zinc. They are generally quite close-grained and heavy, when under good cover. They range in size from an inch to a foot in diameter. They are distributed in the beds of shale or fire-clay that make so large and characteristic a portion of the coal measure strata, and from which their materials have been segregated. Sometimes they are gathered into distinct horizons, which the miner can easily and economically follow, and sometimes they are so sparsely distributed that though the aggregate amount of ore in a bed of shale or clay is considerable, it will not pay for working.

In quality, these ores hold a good rank. They are often very kind and easy to smelt. The weathered kidneys are almost always so. The unweathered masses are frequently too close and stubborn for use in charcoal furnaces. They contain from 35 to 50 per cent. of metallic iron.

There are five or six pretty well marked horizons of kidney ore, some of which are quite persistent and widespread.

The *block ores* are so called from the fact that they are found in horizontal and almost continuous sheets of uniform thickness, but these sheets are of chemical, not mechanical origin. They range in thickness from one or two inches to one or two feet, but the ores that are worked are mostly between four and eight inches in thickness. The separate blocks have the same general structure as the kidney ores last described. They show their concretionary origin in the concentric layers that weathering reveals. These blocks are often fitted to each other like the separate blocks of a tesselated pavement.

They bear a peculiar relation to the coal measure limestones. Without exception, the leading block ores of the field are borne by these limestones, or else, the ores seem to replace and substitute them. They deserve to be called limestone ores from this point of view, and they are so called in some localities, but in Ohio this name is mainly reserved for other phases of iron accumulation.

The block ores of our scale are often mellow and excellent. The weathered ores average a little more than 40 per cent. of metallic iron as a rule.

There are three chief horizons of these ores, and two of them are remarkably persistent, stretching with the limestones that bear them entirely around the field.

The ores that are known as *limestone ores* present two distinct phases. The name is mainly confined to the Hanging Rock district of Southern Ohio, where it is applied to one well-known and very valuable seam, viz., the ore borne by the Ferriferous limestone of the general scale. The designation "limestone ore" is specific in this portion of the State, being exclusively applied to this seam. The ore overlies the limestone, sometimes graduating insensibly into it, and sometimes separate and distinct from it, but lying in close proximity. Above the main sheet of ore, kidneys are generally to be found scattered through the clay. A common and very characteristic form of the unaltered ore of this horizon is found in the so-called gray ore. It consists of minute grains of carbonate of iron, buried in a silicious clay. This form does not blend with the limestone. The most valued form of the ore, especially for use in charcoal furnaces, is the limonite that has resulted from the weathering and transformation of the original carbonate.

A second phase of limestone ore, but not usually recognized by that name, is the replacement of the buff limestones of the Freeport type with carbonate of iron to a greater or less extent. These ores are very uncertain in character, changing from ore to limestone on short notice. On their outcrops they are frequently ores of fair grade, while under cover they are simply ferruginous limestones. The impure limestones of this group are frequently nodular, lying in detached masses in their clays, and when these are transformed into limonites as far as their iron will allow, they pass for kidney ores, but they do not show the same history as the ores to which this name has already been assigned.

The ores of the Lower Coal Measures will all be included under one or another of the forms now described, but distinct attention must be called to a line of facts which has several times, in the course of this discussion, been mentioned incidentally. These ores, while originally carbonates of iron in every case, have been transformed along their lines of outcrop, and often under considerable cover, into hydrated peroxides or limonites. In many instances the transformation has been very thorough, the form, volume, spe-

cific gravity, texture, and color of the ore being changed in the process. The change is always in the line of improvement of the quality of the ore.